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The spectrum of singly ionized argon in the vacuum ultraviolet

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With 2 plates

Introduction

The spectrum of singly ionized argon, Ar II, in the vacuum ultraviolet has been investigated particularly by Dorgelo and Abbink [1], Compton, Boyce and Russell [2], and Boyce [3]. Boyce's extensive measurements, being made by means of a two-meter normal incidence vacuum spectrograph, are very accurate. The identified lines given in the works cited occur in three groups, firstly the few lines between 1973 Å and 1560 Å consisting of $3s3p^6\,{}^2S$–$({}^3P,{}^1D)4p\,{}^2S,{}^2P,{}^2D$ transitions, secondly the two very strong $3s^23p^5\,{}^2P$–$3s3p^6\,{}^2S$ lines $\lambda\lambda$ 932 and 919, and thirdly the majority of lines which lie between 762 Å and 487 Å, all of them transitions to the ground term $3p^5\,{}^2P$ from even-parity levels belonging to the $({}^3P,{}^1D)4s,5s,6s,3d,4d,5d$ and $({}^1S)4s,3d$ configurations.

In the course of the work to extend the analysis of Ar II on the basis of new measurements, completed some time ago but not yet published, in the whole range between 12500 Å and 1900 Å, I realised that important transitions were to be expected in the upper part of the vacuum ultraviolet (the Schumann region). Lines appearing there would be significant in the attempts to find and identify odd levels combining with $({}^3P)4s,3d$ and $({}^1D)3d$ terms, the interest being particularly directed to levels belonging to the $({}^3P,{}^1D)\,\mathrm{n}p,\mathrm{n}f$ configurations. No such lines were given in the papers cited, but the present investigation has shown that 14 lines in Lyman's "blue" argon spectrum are Ar II lines [4].

Since the examination of the Ar II spectrum at longer wavelengths had revealed new levels, which should combine with the ground term, and also had led to the alteration of previous assignments and to the rejection of some levels adopted in current lists, it seemed desirable to extend the new investigation even to the range below 1000 Å in order to check the results [5, 6].

Experimental arrangements

The argon spectrum was excited by means of an electrodeless high-frequency discharge, employing arrangements developed in collaboration with L. Stigmark and described previously [7]. A few remarks on the advantages of this type of discharge in vacuum spectroscopy were made in a preceding paper [8].

The discharge tube was made of fused quartz; its main part was 17 cm long having an outer diameter of 23 mm. It was surrounded by a coil of 5 mm copper wire. The tube widened towards its open end and was completed by a large ground socket by which it was attached to the cone-shaped slit tube of the spectrograph. Through two side-tubes the discharge tube was connected to the gas-circulating system and through a third tube near the slit a shutter was manipulated.

The vacuum spectrograph used was a grazing-incidence instrument with a 1.5 meter N.P.L. grating, the dispersion in the first order being 4.2 Å/mm at 1000 Å [9]. The original slit was replaced by a construction which permits a rapid resetting in a focussed position, the jaws remaining parallel to the grating grooves, after it has been out for cleaning. The slit width, which was at most 4 microns, could easily be adjusted as well. The slit was designed by S. Avellén and is described by him in a subsequent paper. The spectrograph was evacuated continuously by an oil diffusion pump. The pressure in the discharge tube was a few hundredths of a millimeter of mercury, and the leakage through the slit into the spectrograph was compensated for by letting in argon gas from a container through a needle valve.

Most spectrograms were taken on Ilford Q2 and Q1 plates. Because of the small radius of curvature of the Rowland circle, 75 cm, the plates had to be specially made of very thin glass, 0.5–0.8 mm thick. As irregularities in the emulsion layer shift the lines on grazing incidence spectrograms appreciably, the emulsion was supplied on ground glass.

As described in the preceding publications on the excitation of spectra by high-frequency pulses [7, 8] the intensities of spectrum lines belonging to different ionization stages are affected in different ways when the pulse power is changed. This means that the origin of the lines can be settled from the observations. Consequently, at least two exposures with different pulse powers were made on every plate in order to recognize the Ar II lines: one pulse power appropriate to develop the Ar II spectrum as complete as possible, another suited for the Ar III spectrum (Plates I–II).

The 2000–450 Å range was photographed in the first order; not too weak lines below 1000 Å were obtained also in the second order, and lines below about 700 Å even in the third order.

Wavelengths

The argon lines were measured in a Zeiss Abbe-comparator against O I, N I, N II, C I, C II and Ar II standards, the oxygen, nitrogen, and carbon lines being impurity lines. Great improvements in the wavelength accuracy of many of these reference lines have been made lately thanks to Herzberg's [10] accurate measurements with a 3 m vacuum spectrograph in high orders. On the basis of these measurements and measures at longer wavelengths he has calculated very accurate standard lines applying the combination principle. His measure of $2p^4\,{}^3P$–$3s\,{}^3S$ in O I was used by Edlén [11] to recalculate the vacuum ultraviolet O I standards. Also N I and N II wavelengths reported by Eriksson [12, 13] have been used, and a few C I lines from Wilkinson's list [14].

As regards Ar II standards I have used Herzberg's measures of $3p^6\,{}^2S$–$4p\,{}^2S,{}^2P,{}^2D$ directly, and, in addition, wavelengths calculated as follows. On the basis of my measures at longer wavelengths a well-connected energy level system with high relative accuracy was determined. It was used to calculate some $3d$–$4f,5p$, and $4s$–$5p$ lines to be used as reference lines in the Schumann region. Further, this level system

Table 1. Argon II spectrum in the Schumann region.

Intensity	λ (vac)	σ	σ (calc)[1]	Combination	λ (calc)
0	1 993.555	50 161.65	1.39	$(^3P)4p\,^4D_{1\frac{1}{2}}-(^3P)7s\,^4P_{\frac{1}{2}}$[2]	
3 bl?	1 988.620	50 286.13	6.58	$3d\,^2P_{\frac{1}{2}} - 4f\,^4F_{1\frac{1}{2}}$	(1 988.602)
1	1 983.831	50 407.52	7.57	$3d\,^2P_{1\frac{1}{2}} - 4f\,^2D_{1\frac{1}{2}}$	1 983.829
1	1 983.296	50 421.12	1.05	$3d\,^2P_{1\frac{1}{2}} - 4f\,^2F_{2\frac{1}{2}}$	1 983.299
1	1 981.74	50 460.7	0.49	$4p\,^4D_{3\frac{1}{2}} - 6d\,^4D_{3\frac{1}{2}}$?	
0	1 977.200	50 576.57	6.42	$4p\,^4D_{2\frac{1}{2}} - 7s\,^2P_{1\frac{1}{2}}$	
3	1 976.765	50 587.70	7.70	$3d\,^2P_{\frac{1}{2}} - 4f\,^4D_{1\frac{1}{2}}$	1 976.765
3	1 974.467	50 646.58	6.70	$3d\,^2P_{1\frac{1}{2}} - 4f\,^4G_{2\frac{1}{2}}$	1 974.462
2	1 973.4837[3]	50 671.815	1.84	$3p^6\,^2S_{\frac{1}{2}} - 4p\,^2D_{1\frac{1}{2}}$	
2	1 972.270	50 703.00	2.89	$4p\,^4D_{3\frac{1}{2}} - 6d\,^4F_{4\frac{1}{2}}$	1 972.274
1	1 966.952	50 840.08	0.05	$4p\,^2D_{2\frac{1}{2}} - 6d\,^2F_{3\frac{1}{2}}$	1 966.953
3	1 962.164	50 964.14	4.21	$3d\,^2P_{1\frac{1}{2}} - 4f\,^2D_{2\frac{1}{2}}$	1 962.161
4	1 961.3610[3]	50 985.005	5.00	$3p^6\,^2S_{\frac{1}{2}} - 4p\,^2P_{\frac{1}{2}}$	
2	1 946.800	51 366.34	6.47	$3d\,^2P_{\frac{1}{2}} - 4f\,^2D_{1\frac{1}{2}}$	1 946.795
3	1 941.0724[3]	51 517.913	7.88	$3p^6\,^2S_{\frac{1}{2}} - 4p\,^2P_{1\frac{1}{2}}$	
1	1 937.042	51 625.11	5.14	$3d\,^4F_{1\frac{1}{2}} - 4f\,^4F_{1\frac{1}{2}}$	1 937.041
2	1 933.694	51 714.49	4.49	$3d\,^4F_{2\frac{1}{2}} - 4f\,^4F_{3\frac{1}{2}}$	1 933.694
2	1 932.231	51 753.65	3.67	$3d\,^4F_{2\frac{1}{2}} - 4f\,^4F_{2\frac{1}{2}}$	1 932.230
1	1 931.421	51 775.35	5.40	$3d\,^4F_{2\frac{1}{2}} - 4f\,^4D_{3\frac{1}{2}}$	1 931.419
2	1 920.016	52 082.90	3.15	$3d\,^4F_{3\frac{1}{2}} - 4f\,^4F_{4\frac{1}{2}}$	1 920.007
3	1 919.197	52 105.13	5.07	$3d\,^4F_{3\frac{1}{2}} - 4f\,^4F_{3\frac{1}{2}}$	1 919.199
0.5	1 911.046	52 327.36	7.18	$3p^6\,^2S_{\frac{1}{2}} - 4p\,^4S_{1\frac{1}{2}}$	1 911.053
0.5	1 909.5689[3]	52 367.841	7.84	$3p^6\,^2S_{\frac{1}{2}} - 4p\,^2S_{\frac{1}{2}}$	
4	1 907.989	52 411.20	1.24	$3d\,^4F_{3\frac{1}{2}} - 4f\,^4G_{4\frac{1}{2}}$	1 907.988
4	1 900.638	52 613.91	3.91	$3d\,^4F_{4\frac{1}{2}} - 4f\,^4F_{4\frac{1}{2}}$	1 900.638
1	1 899.834	52 636.2	5.82	$3d\,^4F_{4\frac{1}{2}} - 4f\,^4F_{3\frac{1}{2}}$	1 899.847
1	1 899.271	52 651.8	1.35	$4p\,^4P_{2\frac{1}{2}} - 6d\,^4D_{3\frac{1}{2}}$	1 899.287
0.5	1 897.365	52 704.7	5.02	$3d\,^4F_{1\frac{1}{2}} - 4f\,^2D_{1\frac{1}{2}}$	1 897.352
6	1 889.029	52 937.2	7.26	$3d\,^4F_{4\frac{1}{2}} - 4f\,^4G_{5\frac{1}{2}}$	1 889.029
4	1 888.788	52 944.0	4.16	$3d\,^4F_{1\frac{1}{2}} - 4f\,^4G_{2\frac{1}{2}}$	1 888.782
4	1 886.387	53 011.4	1.41	$3d\,^4F_{2\frac{1}{2}} - 4f\,^4G_{3\frac{1}{2}}$	1 886.386
2	1 879.788	53 197.5	7.44	$3d\,^4F_{2\frac{1}{2}} - 4f\,^2G_{3\frac{1}{2}}$	1 879.790
1	1 879.419	53 207.9	7.91	$3d\,^4F_{2\frac{1}{2}} - 4f\,^4G_{2\frac{1}{2}}$	1 879.420
4	1 877.523	53 261.7	1.66	$3d\,^4F_{1\frac{1}{2}} - 4f\,^2D_{2\frac{1}{2}}$	1 877.523
6	1 873.140	53 386.3	6.28	$3d\,^4F_{3\frac{1}{2}} - 4f\,^2G_{4\frac{1}{2}}$	1 873.140
1	1 872.582	53 402.2	1.99	$3d\,^4F_{3\frac{1}{2}} - 4f\,^2G_{3\frac{1}{2}}$	1 872.589
3	1 868.660	53 514.3	4.28	$3d\,^4F_{2\frac{1}{2}} - 4f\,^2F_{3\frac{1}{2}}$	1 868.660
1	1 866.093	53 587.9	8.02	$3d\,^4F_{3\frac{1}{2}} - 4f\,^2G_{3\frac{1}{2}}$	1 866.089
0.5	1 854.986	53 908.8	8.84	$3d\,^4D_{3\frac{1}{2}} - 5f\,^4D_{3\frac{1}{2}}$	
2	1 834.039	54 524.5	4.50	$4s\,^4P_{2\frac{1}{2}} - 5p\,^4P_{2\frac{1}{2}}$	1 834.038
5	1 831.525	54 599.3	9.26	$(^1D)3d\,^2G_{3\frac{1}{2}} - (^1D)4f\,^2H_{4\frac{1}{2}}$	1 831.527
5	1 830.771	54 621.8	1.82	$(^1D)3d\,^2G_{4\frac{1}{2}} - (^1D)4f\,^2H_{5\frac{1}{2}}$	1 830.770
0.5	1 824.842	54 799.3	9.21	$4s\,^4P_{2\frac{1}{2}} - 5p\,^4P_{1\frac{1}{2}}$	
1	1 823.207	54 848.4	8.47	$3d\,^2F_{2\frac{1}{2}} - 5f\,^4D_{3\frac{1}{2}}$	1 823.205
0.5	1 816.14	55 061.8	1.69	$3d\,^2D_{2\frac{1}{2}} - 5f\,^4G_{3\frac{1}{2}}$	

Table 1 (*continued*)

Intensity	λ (vac)	σ	σ (calc)[1]	Combination	λ (calc)
1	1 813.772	55 133.7	3.90	$(^1D)3d\,^2G_{3\frac12}-(^1D)4f\,^2G_{3\frac12}$	1 813.766
1	1 813.009	55 156.9	6.78	$(^1D)3d\,^2G_{4\frac12}-(^1D)4f\,^2G_{4\frac12}$	1 813.014
0.5[4]	1 812.475	55 173.2	3.30	$4s\,^4P_{2\frac12}-5p\,^4D_{3\frac12}$	
0.5	1 793.435	55 758.9	8.63	$3d\,^2F_{3\frac12}-5f\,^4F_{4\frac12}$	
1	1 791.561	55 817.2	6.92	$3d\,^2F_{3\frac12}-5f\,^4D_{3\frac12}$	1 791.571
3	1 788.101	55 925.3	5.15	$3d\,^2F_{3\frac12}-5f\,^4G_{4\frac12}$	1 788.104
1	1 785.669	56 001.4	1.32	$3d\,^2F_{2\frac12}-5f\,^4G_{3\frac12}$	1 785.672
1	1 782.587	56 098.2	7.95	$3d\,^2F_{2\frac12}-5f\,^4G_{3\frac12}$	1 782.596
1	1 776.670	56 285.1	5.00	$3d\,^4D_{2\frac12}-5p\,^4P_{2\frac12}$	1 776.672
2	1 771.829	56 438.9	8.87	$3d\,^4D_{3\frac12}-5p\,^4P_{2\frac12}$	1 771.829
1	1 770.652	56 476.4	6.18	$3d\,^2F_{2\frac12}-5f\,^2F_{3\frac12}$	1 770.658
1	1 768.042	56 559.7	9.72	$3d\,^4D_{2\frac12}-5p\,^4P_{1\frac12}$	1 768.043
0.5	1 763.669	56 700.0	0.07	$3d\,^4D_{\frac12}-5p\,^4P_{\frac12}$	
1[5]	1 755.810	56 953.8	3.49	$3d\,^2F_{3\frac12}-5f\,^2G_{4\frac12}$	1 755.819
2	1 751.679	57 088.1	7.68	$3d\,^4D_{3\frac12}-5p\,^4D_{3\frac12}$	
0.5	1 750.694	57 120.2	0.22	$3d\,^4P_{2\frac12}-5f\,^4D_{3\frac12}$	
1	1 736.830	57 576.2	6.04	$3d\,^4P_{1\frac12}-5f\,^4D_{2\frac12}$	1 736.834
0.5	1 735.378	57 624.3	5.08	$3d\,^4D_{2\frac12}-5p\,^4D_{1\frac12}$	
1	1 733.362	57 691.4	1.01	$3d\,^4P_{1\frac12}-5f\,^4D_{1\frac12}$	1 733.372
1	1 729.262	57 828.1	8.25	$3d\,^4P_{\frac12}-5f\,^4F_{1\frac12}$	1 729.259
1	1 729.075	57 834.4	3.95 6.17	$3d\,^2D_{2\frac12}-(^1D)4f\,^2D_{2\frac12}$ $3d\,^2D_{2\frac12}-(^1D)4f\,^2D_{1\frac12}$	
0.5	1 725.549	57 952.6	2.39	$3d\,^4P_{\frac12}-5f\,^4D_{\frac12}$	
1	1 725.138	57 966.4	6.07	$3d\,^4P_{\frac12}-5f\,^4D_{1\frac12}$	1 725.147
2	1 719.346	58 161.6	1.30 4.23	$3d\,^2D_{2\frac12}-(^1D)4f\,^2F_{3\frac12}$ $3d\,^2D_{2\frac12}-(^1D)4f\,^2F_{2\frac12}$	
1	1 718.680	58 184.2	3.92	$3d\,^4D_{3\frac12}-5p\,^2D_{2\frac12}$	
2	1 713.215	58 369.8	9.70	$3d\,^4P_{2\frac12}-5f\,^2G_{3\frac12}$	1 713.218
0.5	1 710.909	58 448.5	6.30 8.52	$3d\,^2D_{1\frac12}-(^1D)4f\,^2D_{2\frac12}$ $3d\,^2D_{1\frac12}-(^1D)4f\,^2D_{1\frac12}$	
1	1 705.977	58 617.4	7.32	$3d\,^4P_{1\frac12}-5f\,^2F_{2\frac12}$	1 705.980
1	1 702.186	58 748.0	7.93	$3d\,^4P_{2\frac12}-5f\,^2F_{3\frac12}$	1 702.188
1	1 701.358	58 776.6	6.57	$3d\,^2D_{1\frac12}-(^1D)4f\,^2F_{2\frac12}$	1 701.358
0.5	1 689.470	59 190.2	0.25	$3d\,^2F_{2\frac12}-(^1D)4f\,^2G_{3\frac12}$	
0.5	1 686.076	59 309.3	8.78	$3d\,^2P_{1\frac12}-5f\,^4F_{2\frac12}$?	
1	1 662.253	60 159.3	8.70 9.04	$3d\,^2F_{3\frac12}-(^1D)4f\,^2G_{3\frac12}$ $3d\,^2F_{3\frac12}-(^1D)4f\,^2G_{4\frac12}$	
1	1 653.322	60 484.3	4.13	$3d\,^2P_{\frac12}-5f\,^4D_{1\frac12}$	
1	1 650.531	60 586.6	6.42	$3d\,^2P_{1\frac12}-5f\,^4G_{2\frac12}$	1 650.535
1	1 640.335	60 963.2	2.86	$3d\,^2P_{1\frac12}-5f\,^2D_{2\frac12}$	1 640.343
1[6]	1 629.834	61 355.9	5.72	$3d\,^2F_{3\frac12}-6f\,^4G_{4\frac12}$	
1[7]	1 628.825	61 393.9	3.57	$3d\,^2P_{\frac12}-5f\,^2D_{1\frac12}$	
0	1 627.085	61 459.6	8.84	$3d\,^2F_{2\frac12}-6f\,^4G_{3\frac12}$?	
1	1 616.972	61 844.0	3.49	$3d\,^4F_{2\frac12}-5f\,^4F_{3\frac12}$	
0.5	1 615.807	61 888.6	8.49	$3d\,^4F_{2\frac12}-5f\,^4D_{3\frac12}$	

Table 1 (*continued*)

Intensity	λ (vac)	σ	σ (calc)[1]	Combination	λ (calc)
1	1 607.168	62 221.2	0.78	$3d\,{}^4F_{3\frac12}-\quad 5f\,{}^4F_{4\frac12}$	1 607.180
4	1 606.927	62 230.6	0.62	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^4F_{2\frac12}$	1 606.926
3	1 606.197	62 258.9	8.88	$3d\,{}^4D_{\frac12}-\quad 4f\,{}^4F_{1\frac12}$	1 606.197
5	1 604.083	62 340.9	0.95	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4F_{3\frac12}$	1 604.082
4	1 603.443	62 365.8	5.84	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^4F_{1\frac12}$	1 603.442
4	1 603.074	62 380.2	0.12	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4F_{2\frac12}$	1 603.075
2	1 602.893	62 387.2	7.29	$3d\,{}^4F_{3\frac12}-\quad 5f\,{}^4G_{4\frac12}$	1 602.891
2	1 602.554	62 400.4	0.47 1.86	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^4D_{2\frac12}$ $3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4D_{3\frac12}$	
6	1 600.694	62 472.9	2.90	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^4F_{4\frac12}$	1 600.694
4	1 600.133	62 494.8	4.81	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^4F_{3\frac12}$	1 600.133
1	1 599.597	62 515.7	5.34	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4F_{1\frac12}$	1 599.607
1	1 599.125	62 534.2	3.99	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^4F_{2\frac12}$	1 599.130
1	1 598.872	62 544.1	3.77	$3d\,{}^4D_{\frac12}-\quad 4f\,{}^4D_{\frac12}$	1 598.880
2	1 598.724	62 549.9	9.97	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4D_{2\frac12}$	1 598.722
1	1 598.561	62 556.3	5.72	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^4D_{3\frac12}$	1 598.575
1	1 596.141	62 651.1	0.73	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^4D_{\frac12}$	1 596.151
1	1 595.734	62 667.1	6.96	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^4D_{1\frac12}$	1 595.737
1	1 594.787	62 704.3	3.84	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^4D_{2\frac12}$	1 594.799
2	1 593.581	62 751.8	1.53	$3d\,{}^4F_{4\frac12}-\quad 5f\,{}^4F_{4\frac12}$	1 593.587
1	1 591.933	62 816.7	6.46	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4D_{1\frac12}$	1 591.939
2	1 590.229	62 884.0	3.87	$3d\,{}^4F_{1\frac12}-\quad 5f\,{}^4G_{2\frac12}$	1 590.233
5	1 589.463	62 914.3	4.25	$3d\,{}^4F_{4\frac12}-\quad 5f\,{}^4G_{5\frac12}$	1 589.465
2	1 586.256	63 041.5	1.34	$3d\,{}^4F_{2\frac12}-\quad 5f\,{}^4G_{3\frac12}$	1 586.261
1	1 583.83	63 138.1	7.97	$3d\,{}^4F_{2\frac12}-\quad 5f\,{}^2G_{3\frac12}$	1 583.833
1	1 580.960	63 252.7	2.39 4.61	$3d\,{}^2P_{1\frac12}-({}^1D)4f\,{}^2D_{2\frac12}$ $3d\,{}^2P_{1\frac12}-({}^1D)4f\,{}^2D_{1\frac12}$	1 580.968
2	1 580.768	63 260.4	0.31	$3d\,{}^4F_{1\frac12}-\quad 5f\,{}^2D_{2\frac12}$	1 580.770
3	1 578.812	63 338.8	8.76	$3d\,{}^4D_{\frac12}-\quad 4f\,{}^2D_{1\frac12}$	1 578.812
3	1 576.897	63 415.7	5.64	$3d\,{}^4F_{3\frac12}-\quad 5f\,{}^2G_{4\frac12}$	1 576.898
3	1 575.815	63 459.2	9.21	$3d\,{}^4D_{1\frac12}-\quad 4f\,{}^2F_{2\frac12}$	1 575.815
6	1 574.992	63 492.4	2.33	$3p^6\,{}^2S_{\frac12}-({}^1D)4p\,{}^2P_{1\frac12}$	1 574.993
1	1 574.402	63 516.2	6.20	$3d\,{}^4F_{2\frac12}-\quad 5f\,{}^2F_{3\frac12}$	1 574.401
1	1 571.390	63 637.9	7.87	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^4G_{3\frac12}$	1 571.391
4	1 567.987	63 776.0	6.02	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^2G_{4\frac12}$	1 567.987
1	1 566.812	63 823.9	3.90	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^2G_{3\frac12}$	1 566.811
1	1 565.377	63 882.4	1.86 2.20	$3d\,{}^2P_{\frac12}-({}^1D)4f\,{}^2P_{\frac12}$ $3d\,{}^2P_{\frac12}-({}^1D)4f\,{}^2P_{1\frac12}$	
1	1 563.036	63 978.1	7.76	$3d\,{}^4D_{3\frac12}-\quad 4f\,{}^2G_{3\frac12}$	1 563.043
2	1 562.441	64 002.4	2.37	$3d\,{}^2D_{1\frac12}-\quad 4f\,{}^2D_{2\frac12}$	1 562.442
4	1 560.184	64 095.0	4.73	$3p^6\,{}^2S_{\frac12}-({}^1D)4p\,{}^2P_{\frac12}$	1 560.191
3	1 559.072	64 140.7	0.74	$3d\,{}^4D_{2\frac12}-\quad 4f\,{}^2F_{3\frac12}$	1 559.072
1	1 557.302	64 213.6	3.51	$3d\,{}^2P_{\frac12}-({}^1D)4f\,{}^2D_{1\frac12}$	1 557.305
1	1 547.354	64 626.5	6.36	$3p^6\,{}^2S_{\frac12}-({}^1D)4\mathrm{p}\,{}^2D_{1\frac12}$	1 547.356
2	1 544.711	64 737.0	$5f\,{}^2H_{4\frac12}$	$({}^1D)3d\,{}^2G_{3\frac12}-({}^1D)5f\,{}^2H_{4\frac12}$	

Table 1 (*continued*)

Intensity	λ (vac)	σ	σ (calc)[1]	Combination	λ (calc)
2	1 544.177	64 759.4	$5f\,^2H_{5\frac{1}{2}}$	$(^1D)3d\,^2G_{4\frac{1}{2}}-(^1D)5f\,^2H_{5\frac{1}{2}}$	
1	1 474.537	67 817.9	7.87	$3d\,^4F_{3\frac{1}{2}}-\ 6f\,^4G_{4\frac{1}{2}}$	1 474.538
1	1 465.153	68 252.3	2.3	$3d\,^4F_{4\frac{1}{2}}-\ 6f\,^4F_{4\frac{1}{2}}$	
1	1 464.176	68 297.8	7.82	$3d\,^4F_{1\frac{1}{2}}-\ 6f\,^4G_{2\frac{1}{2}}$	
2	1 463.155	68 345.5	$6f\,^4G_{5\frac{1}{2}}$	$3d\,^4F_{4\frac{1}{2}}-\ 6f\,^4G_{5\frac{1}{2}}$	
1	1 459.875	68 499.0	8.86	$3d\,^4F_{2\frac{1}{2}}-\ 6f\,^4G_{3\frac{1}{2}}$	1 459.878
1	1 455.484	68 705.7	5.6	$3d\,^4F_{1\frac{1}{2}}-\ 6f\,^2D_{2\frac{1}{2}}$	
1	1 451.879	68 876.3	$6f\,^2G_{4\frac{1}{2}}$	$3d\,^4F_{3\frac{1}{2}}-\ 6f\,^2G_{4\frac{1}{2}}$?	
1	1 396.231	71 621.4	$7f\,^4G_{5\frac{1}{2}}$	$3d\,^4F_{4\frac{1}{2}}-\ 7f\,^4G_{5\frac{1}{2}}$?	
1	1 382.765	72 318.9	8.60	$3d\,^4D_{\frac{1}{2}}-\ 5f\,^4F_{1\frac{1}{2}}$	1 382.770
2	1 382.228	72 347.0	6.94	$3d\,^4D_{1\frac{1}{2}}-\ 5f\,^4F_{2\frac{1}{2}}$	1 382.228
1	1 380.723	72 425.8	5.57	$3d\,^4D_{1\frac{1}{2}}-\ 5f\,^4F_{1\frac{1}{2}}$	1 380.728
3	1 379.884	72 469.9	9.95	$3d\,^4D_{2\frac{1}{2}}-\ 5f\,^4F_{3\frac{1}{2}}$	
1	1 379.377	72 496.5	6.44	$3d\,^4D_{2\frac{1}{2}}-\ 5f\,^4F_{2\frac{1}{2}}$	1 379.378
0	1 377.442	72 598.3	7.92	$3d\,^4D_{2\frac{1}{2}}-\ 5f\,^4D_{2\frac{1}{2}}$	
4	1 377.211	72 610.5	0.52	$3d\,^4D_{3\frac{1}{2}}-\ 5f\,^4F_{4\frac{1}{2}}$	1 377.211
1	1 376.956	72 624.0	3.81	$3d\,^4D_{3\frac{1}{2}}-\ 5f\,^4F_{3\frac{1}{2}}$	
0.5	1 376.107	72 668.8	8.81	$3d\,^4D_{3\frac{1}{2}}-\ 5f\,^4D_{3\frac{1}{2}}$	1 376.106
2	1 363.031	73 365.9	5.83	$3d\,^4D_{\frac{1}{2}}-\ 5f\,^2D_{1\frac{1}{2}}$	1 363.032
1	1 360.735	73 489.7	9.70	$3d\,^4D_{1\frac{1}{2}}-\ 5f\,^2F_{2\frac{1}{2}}$	1 360.735
0	1 357.435	73 668.4	7.80	$3d\,^4D_{2\frac{1}{2}}-\ 5f\,^4G_{3\frac{1}{2}}$?	
2	1 354.912	73 805.5	5.38	$3d\,^4D_{3\frac{1}{2}}-\ 5f\,^2G_{4\frac{1}{2}}$	1 354.915
1	1 351.330	74 001.2	1.02	$3d\,^4D_{1\frac{1}{2}}-\ 5f\,^2\mathrm{D}_{2\frac{1}{2}}$	1 351.333
1	1 348.745	74 143.0	2.65	$3d\,^4D_{2\frac{1}{2}}-\ 5f\,^2F_{3\frac{1}{2}}$	1 348.751
1	1 284.793	77 833.5	4.06	$3d\,^4D_{1\frac{1}{2}}-\ 6f\,^4F_{2\frac{1}{2}}$	
1	1 282.620	77 965.4	5.97	$3d\,^4D_{2\frac{1}{2}}-\ 6f\,^4F_{3\frac{1}{2}}$	
1	1 280.225	78 111.3	1.3	$3d\,^4D_{3\frac{1}{2}}-\ 6f\,^4F_{4\frac{1}{2}}$	
1	1 268.483	78 834.3	4.66	$3d\,^4D_{\frac{1}{2}}-\ 6f\,^2D_{1\frac{1}{2}}$?	

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[1] A symbol in this column means that the level value was computed from this line only.

[2] The (^1D) and (^1S) limits only are marked in the table, the (^3P) limit symbol has been omitted.

[3] Measured by Herzberg.

[4] Blended by 3rd order ArIII line.

[5] Blended by 2nd order OII line?

[6] Blended by NII line?

[7] Blended by 3rd order ArII line?

was fixed in relation to the ground term by using Herzberg's measures for $3p^6\,^2S$–$4p\,^2S,^2P,^2D$ and $3p^5\,^2P$–$3p^6\,^2S$ in the vacuum ultraviolet, and transitions to the ground term from several even-parity levels were computed. These lines, well-suited as standards, lie below 762 Å (Table 2, column 6). Their accuracy, which mainly depends on the accuracy of the λ 932 and λ 919 wavelengths, is estimated to be about ± 0.0005 Å. Herzberg has calculated a number of such standards from his own measurements of selected lines at longer wavelengths. The agreement of his calculated vacuum ultraviolet standards with those calculated in the present work is extremely good.

Table 2. Argon II spectrum below 1000 Å.

Intensity	λ (vac)	σ	σ (calc)	Combination	λ (calc)
10	932.0528[1]	107 290.06		$3p^5\,{}^2P_{\frac{1}{2}} - 3p^6\,{}^2S_{\frac{1}{2}}$	
10	919.7815[1]	108 721.47		$3p^5\,{}^2P_{1\frac{1}{2}} - 3p^6\,{}^2S_{\frac{1}{2}}$	
3	762.200	131 199.2	9.24	$3p^5\,{}^2P_{\frac{1}{2}} - ({}^3P)\,3d\,{}^4D_{1\frac{1}{2}}$[2]	762.1995
3	754.824	132 481.2	1.15	${}^2P_{1\frac{1}{2}} - 3d\,{}^4D_{2\frac{1}{2}}$	754.8243
4	748.198	133 654.5	4.51	${}^2P_{\frac{1}{2}} - 4s\,{}^4P_{1\frac{1}{2}}$	748.1977
7	745.323	134 170.0	0.25	${}^2P_{\frac{1}{2}} - 4s\,{}^4P_{\frac{1}{2}}$	745.3217
8	744.925	134 241.7	1.66	${}^2P_{1\frac{1}{2}} - 4s\,{}^4P_{2\frac{1}{2}}$	744.9252
10	740.270	135 085.8	5.92	${}^2P_{1\frac{1}{2}} - 4s\,{}^4P_{1\frac{1}{2}}$	740.2695
1	737.457	135 601.1	1.66	${}^2P_{1\frac{1}{2}} - 4s\,{}^4P_{\frac{1}{2}}$	737.4541
5	730.929	136 812.2	2.14	${}^2P_{\frac{1}{2}} - 4s\,{}^2P_{1\frac{1}{2}}$	730.9293
4	725.550	137 826.5	6.84	${}^2P_{\frac{1}{2}} - 4s\,{}^2P_{\frac{1}{2}}$	725.5481
5	723.361	138 243.6	3.55	${}^2P_{1\frac{1}{2}} - 4s\,{}^2P_{1\frac{1}{2}}$	723.3611
4	718.091	139 258.1	8.25	${}^2P_{1\frac{1}{2}} - 4s\,{}^2P_{\frac{1}{2}}$	718.0903
4	704.523	141 940.0	39.95	${}^2P_{\frac{1}{2}} - 3d\,{}^4F_{1\frac{1}{2}}$	704.5233
4	698.771	143 108.4	7.60	${}^2P_{1\frac{1}{2}} - 3d\,{}^4F_{2\frac{1}{2}}$	698.7748
2	697.940	143 278.8	8.50	${}^2P_{\frac{1}{2}} - 3d\,{}^2P_{\frac{1}{2}}$	697.9414
2	697.489	143 371.4	1.36	${}^2P_{1\frac{1}{2}} - 3d\,{}^4F_{1\frac{1}{2}}$	697.4893
2	693.301	144 237.5	7.40	${}^2P_{\frac{1}{2}} - 3d\,{}^2P_{1\frac{1}{2}}$	693.3015
1	691.038	144 709.8	9.91	${}^2P_{1\frac{1}{2}} - 3d\,{}^2P_{\frac{1}{2}}$	691.0377
2	686.489	145 668.8	8.81	${}^2P_{1\frac{1}{2}} - 3d\,{}^2P_{1\frac{1}{2}}$	686.4888
6	679.400	147 188.7	8.67	${}^2P_{\frac{1}{2}} - ({}^1D)4s\,{}^2D_{1\frac{1}{2}}$	679.4001
3	679.221	147 227.5	7.97	${}^2P_{1\frac{1}{2}} - 3d\,{}^4P_{\frac{1}{2}}$	679.2187
5	677.951	147 503.3	3.03	${}^2P_{1\frac{1}{2}} - 3d\,{}^4P_{1\frac{1}{2}}$	677.9521
6	676.241	147 876.3	5.87	${}^2P_{1\frac{1}{2}} - 3d\,{}^4P_{2\frac{1}{2}}$	676.2428
2	672.856	148 620.2	0.08	${}^2P_{1\frac{1}{2}} - ({}^1D)4s\,{}^2D_{1\frac{1}{2}}$	672.8565
6	671.852	148 842.3	2.38	${}^2P_{1\frac{1}{2}} - ({}^1D)4s\,{}^2D_{2\frac{1}{2}}$	671.8516
5	670.948	149 042.8	3.49	${}^2P_{\frac{1}{2}} - 3d\,{}^2D_{1\frac{1}{2}}$	670.9450
6	666.010	150 147.9	7.62	${}^2P_{1\frac{1}{2}} - 3d\,{}^2F_{2\frac{1}{2}}$	666.0112
4	664.563	150 474.8	4.90	${}^2P_{1\frac{1}{2}} - 3d\,{}^2D_{1\frac{1}{2}}$	664.5626
5	661.869	151 087.3	7.25	${}^2P_{1\frac{1}{2}} - 3d\,{}^2D_{2\frac{1}{2}}$	661.8692
5	612.371	163 299.7	9.47	${}^2P_{1\frac{1}{2}} - ({}^1D)3d\,{}^2F_{2\frac{1}{2}}$	612.3719
2	602.858	165 876.5	6.51	${}^2P_{\frac{1}{2}} - ({}^1S)4s\,{}^2S_{\frac{1}{2}}$	602.8581
2	597.701	167 307.7	7.92	${}^2P_{1\frac{1}{2}} - ({}^1S)4s\,{}^2S_{\frac{1}{2}}$	597.7003
2	583.437	171 398.1	8.17	${}^2P_{\frac{1}{2}} - ({}^1D)3d\,{}^2D_{1\frac{1}{2}}$	583.4368
3	580.264	172 335.4	5.52	${}^2P_{1\frac{1}{2}} - ({}^1D)3d\,{}^2D_{2\frac{1}{2}}$	580.2634
2	578.604	172 829.8	9.58	${}^2P_{1\frac{1}{2}} - ({}^1D)3d\,{}^2D_{1\frac{1}{2}}$	578.6046
2	578.107	172 978.4	8.42	${}^2P_{\frac{1}{2}} - ({}^1D)3d\,{}^2P_{1\frac{1}{2}}$	578.1068
2	576.738	173 389.0	9.52	${}^2P_{\frac{1}{2}} - ({}^1D)3d\,{}^2P_{\frac{1}{2}}$	576.7361
2	573.364	174 409.3	9.83	${}^2P_{1\frac{1}{2}} - ({}^1D)3d\,{}^2P_{1\frac{1}{2}}$	573.3622
2	572.014	174 820.9	0.93	${}^2P_{1\frac{1}{2}} - ({}^1D)3d\,{}^2P_{\frac{1}{2}}$	572.0139
2	560.224	178 500.0	0.36	${}^2P_{\frac{1}{2}} - ({}^1S)3d\,{}^2D_{1\frac{1}{2}}$	560.2229
2	556.817	179 592.2	2.13	${}^2P_{1\frac{1}{2}} - ({}^1S)3d\,{}^2D_{2\frac{1}{2}}$	556.8172
1	555.764	179 932.5	1.77	${}^2P_{1\frac{1}{2}} - ({}^1S)3d\,{}^2D_{1\frac{1}{2}}$	555.7662
1	553.123	180 791.6	0.63	${}^2P_{\frac{1}{2}} - 5s\,{}^4P_{1\frac{1}{2}}$	553.1260

Table 2 (*continued*)

Intensity	λ (vac)	σ	σ (calc)	Combination	λ (calc)
1	550.896	181 522.5	19.74	${}^2P_{\frac{1}{2}}-\quad 5s\,{}^4P_{\frac{1}{2}}$	550.9042
1	550.481	181 659.3	9.41	${}^2P_{\frac{1}{2}}-\quad 5s\,{}^2P_{1\frac{1}{2}}$	550.4807
2	548.781	182 222.1	2.04	${}^2P_{1\frac{1}{2}}-\quad 5s\,{}^4P_{1\frac{1}{2}}$	548.7810
0.5	547.992	182 484.4	3.14	${}^2P_{\frac{1}{2}}-\quad 5s\,{}^2P_{\frac{1}{2}}$	547.9958
2	547.456	182 663.1	1.65	${}^2P_{\frac{1}{2}}-({}^1D)3d\,{}^2S_{\frac{1}{2}}$	547.4602
2	547.166	182 759.9	60.31	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^4D_{\frac{1}{2}}$	547.1647
2	546.175	183 091.5	0.82	${}^2P_{1\frac{1}{2}}-\quad 5s\,{}^2P_{1\frac{1}{2}}$	546.1770
2	543.730	183 914.8	4.55	${}^2P_{\frac{1}{2}}-\quad 5s\,{}^2P_{\frac{1}{2}}$	543.7307
0[3]	543.508		5.94	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^4D_{1\frac{1}{2}}$?	(543.5197)
2	543.205	184 092.6	3.06	${}^2P_{1\frac{1}{2}}-({}^1D)3d\,{}^2S_{\frac{1}{2}}$	543.2035
2	542.911	184 192.3	1.72	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^4D_{\frac{1}{2}}$	542.9125
0.5	541.299	184 740.8	39.85	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^4P_{\frac{1}{2}}$	541.3017
0.5	540.804	184 909.9	9.07	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^4F_{1\frac{1}{2}}$	540.8063
0.5[4]	537.421	186 073.9	4.36	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^4F_{2\frac{1}{2}}$	537.4195
1	537.140	186 171.2	1.26	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^4P_{\frac{1}{2}}$	537.1398
0.5	535.072	186 890.7	0.95	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^4P_{2\frac{1}{2}}$	535.0713
1	533.082	187 588.4	9.23	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^2F_{2\frac{1}{2}}$	533.0796
1[5]	530.494	188 503.5	3.14	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^2P_{\frac{1}{2}}$	530.4951
0.5	528.640	189 165	0.76	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^2P_{1\frac{1}{2}}$	528.6508
1	526.497	189 934.6	4.55	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^2P_{\frac{1}{2}}$	526.4971
1	524.683	190 591.3	2.17	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^2P_{1\frac{1}{2}}$	524.6805
1	522.791	191 281.0	0.60	${}^2P_{\frac{1}{2}}-\quad 4d\,{}^2D_{1\frac{1}{2}}$	522.7921
1	519.329	192 556.2	6.84	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^2D_{2\frac{1}{2}}$	519.3271
1	518.910	192 711.6	2.00	${}^2P_{1\frac{1}{2}}-\quad 4d\,{}^2D_{1\frac{1}{2}}$	518.9090
1	514.310	194 435.3	5.35	${}^2P_{\frac{1}{2}}-({}^1D)5s\,{}^2D_{1\frac{1}{2}}$	514.3097
1	510.554	195 865.7	4.65 6.76	${}^2P_{1\frac{1}{2}}-({}^1D)5s\,{}^2D_{2\frac{1}{2}}$ ${}^2P_{1\frac{1}{2}}-({}^1D)5s\,{}^2D_{1\frac{1}{2}}$	510.5566 510.5511
0.5	505.013	198 014.7	5.13	${}^2P_{\frac{1}{2}}-({}^1D)4d\,{}^2P_{\frac{1}{2}}$	505.0119
0.5	503.649		198 550.53	${}^2P_{\frac{1}{2}}-({}^1D)4d\,{}^2P_{1\frac{1}{2}}$	503.6501
1	502.157		199 138.44	${}^2P_{1\frac{1}{2}}-\quad 6s\,{}^4P_{1\frac{1}{2}}$	502.1632
0	501.993		199 192.29	${}^2P_{\frac{1}{2}}-\quad 6s\,{}^2P_{\frac{1}{2}}$	502.027
0.5	501.184		199 525.15	${}^2P_{1\frac{1}{2}}-({}^1D)4d\,{}^2D_{1\frac{1}{2}}$	501.1899
0.5	500.798		199 679.75	${}^2P_{1\frac{1}{2}}-({}^1D)4d\,{}^2D_{2\frac{1}{2}}$	500.8019
0.5	496.650		201 351.55 201 345.23	${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^4F_{2\frac{1}{2}}$? ${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^4P_{1\frac{1}{2}}$?	496.6594 496.6438
0.5	494.686		202 155.87	${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^2F_{2\frac{1}{2}}$?	494.6678
0	492.418		203 083.59	${}^2P_{\frac{1}{2}}-\quad 5d\,{}^2P_{\frac{1}{2}}$	492.4080
0.5	490.698		203 790.07	${}^2P_{\frac{1}{2}}-\quad 5d\,{}^2D_{1\frac{1}{2}}$	490.7010
0.5	489.196		204 417.25	${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^2P_{1\frac{1}{2}}$	489.1955
0	488.987		204 515.00	${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^2P_{\frac{1}{2}}$	488.9616
0.5	488.782		204 585.65	${}^2P_{1\frac{1}{2}}-\quad 5d\,{}^2D_{2\frac{1}{2}}$	488.7928
0	487.264		205 242.96	${}^2P_{1\frac{1}{2}}-({}^1D)4d\,{}^2S_{\frac{1}{2}}$	487.2274

[1] Measured by Herzberg.

[2] The (${}^1D$) and (${}^1S$) limits only are marked in the table, the (${}^3P$) limit symbol has been omitted.

[3] Masked by CII line?

[4] Affected by ArIII line.

[5] Affected by ArIII line?

The argon spectrum and the reference lines were emitted simultaneously from the light source.

The computation of the wavelengths from the comparator readings was made by means of a four-point Lagrange interpolation formula by using a digital computer (The Electronic Computer of Lund University). The constants of the formula were first calculated by the computer from four reference lines, and subsequently all comparator readings were fed into the computer, which calculated the corresponding wavelengths very rapidly and recorded them in tabular form. Several formulas were used to cover a whole spectrogram. A final correction of the wavelengths was made by means of a correction curve based on all suitable standard lines appearing in the range covered by the interpolation formula.

The wavelengths are given in column 2 of Table 1 (Schumann region) and Table 2 (wavelengths below 1000 Å); even those calculated Ar II lines which have been used as reference lines are included in the same column with the wavelengths as read from the correction curve. The measurements in the first order of a Jarrell–Ash 21-foot grating spectrograph (JA 71–15, dispersion about 5 Å/mm) in the 2000–1900 Å range are also given in Table 1.

The observed wavelengths are as a rule mean values of measurements on several spectrograms, and the error is estimated to be a few thousandths of an ångström. The lines below 505 Å, however, were measured on a single spectrogram only.

The intensities in column 1 are estimates of the photographic density.

Results

1. *Schumann region (2000–1200 Å)*

About 150 new Ar II lines were observed in the 2000–1200 Å range. They were added to the above-mentioned list of measurements between 12 500 Å and 1900 Å, as yet unpublished, and the whole material was analysed.

Even before the vacuum measures were started all $(^3P)4f$ levels not previously known were identified from the long-wavelength measurements, as were the $(^3P)5p$ quartets and all $(^3P)6d$ terms, most $(^3P)5p$ doublets being known from previous investigations. Consequently, a great number of vacuum lines could be identified as $(^3P)3d$–$(^3P)4f$, $(^3P)4s$–$(^3P)5p$, $(^3P)3d$–$(^3P)5p$, and $(^3P)4p$–$(^3P)6d$ transitions as soon as they were recognized experimentally as Ar II lines.

The measurements in the Schumann region were important particularly in finding and identifying the $(^3P)5f$ and $6f$ levels. After the levels had been found it was in most cases possible to compute accurate level values from at least one long-wavelength line. Some of the $(^3P)3d$–$(^3P)4f$ and $(^3P)3d$–$(^3P)5f$ multiplets are shown in Tables 3 and 4; part of the $3d$–$4f$ multiplets lie above 2000 Å. Although the coupling is far from Russell-Saunders for the nf configurations, LS symbols have been used in the tables; the coupling conditions will be discussed in a forthcoming paper.

Two rather strong lines, λ 1831 and λ 1830, were identified as $(^1D)3d\,^2G$–$(^1D)4f\,^2H$, and settled definitively the $(^1D)3d\,^2G$ term [6], and two weaker lines, λλ 1813.772 and 1813.009, were found to form the $(^1D)3d\,^2G$–$(^1D)4f\,^2G$ doublet. The wavenumber separation of the medium-intensity lines 1544.711 Å and 1544.177 Å agrees with the $(^1D)3d\,^2G$ separation, indicating the identification $(^1D)3d\,^2G$–$(^1D)5f\,^2H$; no more transitions from the $(^1D)5f\,^2H$ term were found, but a comparison of the 1544 Å line intensities with the intensities of $(^1D)3d\,^2G$–$(^1D)4f$ and a study of the effective quantum

Table 3. $(^3P)3d$–$(^3P)4f$ multiplets.[a]

	$(^3P)4f\,^4D_{3\frac{1}{2}}$ 194 883.00	$4f\,^4D_{2\frac{1}{2}}$ 195 031.12	$4f\,^4D_{1\frac{1}{2}}$ 195 297.61	$4f\,^4D_{\frac{1}{2}}$ 195 281.38	$4f\,^4F_{4\frac{1}{2}}$ 194 800.18	$4f\,^4F_{3\frac{1}{2}}$ 194 822.10	$4f\,^4F_{2\frac{1}{2}}$ 194 861.27	$4f\,^4F_{1\frac{1}{2}}$ 194 996.49	$4f\,^4G_{5\frac{1}{2}}$ 195 123.54	$4f\,^4G_{4\frac{1}{2}}$ 195 128.27	$4f\,^4G_{3\frac{1}{2}}$ 196 119.02	$4f\,^4G_{2\frac{1}{2}}$ 196 315.51
$(^3P)\,3d\,^4P_{2\frac{1}{2}}$ 147 875.87	4 2 126.670 47 007.02	3 2 119.986 47 155.22	2 2 108.071 47 421.71			4 2 129.429 46 946.13	3 2 127.642 46 985.55	1 2 121.544 47 120.58			1h aff Si II 2 072.132 48 244.08	2 2 063.761 48 439.73
$3d\,^4P_{1\frac{1}{2}}$ 147 503.03		5 2 103.356 47 528.00	5 2 091.628 47 794.45	3 2 092.333 47 778.35			2 2 110.895 47 358.26	3 2 104.884 47 493.51				2 2 047.995 48 812.59
$3d\,^4P_{\frac{1}{2}}$ 147 227.97			4 2 079.655 48 069.57	5 2 080.359 48 053.31				3 2 092.765 47 768.49				
$3d\,^4D_{3\frac{1}{2}}$ 132 327.28	1 1 598.561 62 556.3	1 1 594.787 62 704.3			6 1 600.694 62 472.9	4 1 600.133 62 494.8	1 1 599.125 62 534.2					
$3d\,^4D_{2\frac{1}{2}}$ 132 481.15	(m CII 1 602.554 62 400.4)	2 1 598.724 62 549.9	1 1 591.933 62 816.7			5 1 604.083 62 340.9	4 1 603.074 62 380.2	1 1 599.597 62 515.7			1 1 571.390 63 637.9	
$3d\,^4D_{1\frac{1}{2}}$ 132 630.65		(m CII 1 602.554 62 400.4)	1 1 595.734 62 667.1	1 1 596.141 62 651.1			4 1 606.927 62 230.6	4 1 603.443 62 365.8				
$3d\,^4D_{\frac{1}{2}}$ 132 737.62				1 1 598.872 62 544.1				3 1 606.197 62 258.9				
$3d\,^4F_{4\frac{1}{2}}$ 142 186.28					4 1 900.638 52 613.91	1 1 899.834 52 636.18			6 1 889.029 52 937.25			
$3d\,^4F_{3\frac{1}{2}}$ 142 717.03					2 1 920.016 52 082.90	3 1 919.197 52 105.13				4 1 907.989 52 411.20	1 1 872.582 53 402.20	
$3d\,^4F_{2\frac{1}{2}}$ 143 107.60	1 1 931.421 51 775.35					2 1 933.694 51 714.49	2 1 932.231 51 753.65				4 1 886.387 53 011.39	1 1 879.419 53 207.93
								1				4

numbers shows that the identification is correct. The $(^1D)4f$ terms also combine with the $(^3P)3d$ doublet terms as can be seen in Table 1, λλ 1729, 1719, 1710, 1701, 1689, 1662, 1580, 1565, 1557 Å.

Combinations of $(^3P)4p\,^2S, ^2P, ^2D, (^1D)4p\,^2P$ with $3s3p^6\,^2S$ were first reported by Boyce [3]. Now the $3p^6\,^2S_{\frac{1}{2}}-(^1D)4p\,^2D_{1\frac{1}{2}}$ line, λ 1547, has been observed, and also combinations with $(^3P)4p$ quartets, viz. λ 1911, $3p^6\,^2S_{\frac{1}{2}}-(^3P)4p\,^4S_{1\frac{1}{2}}$, and, above 2000 Å, $3p^6\,^2S_{\frac{1}{2}}-(^3P)4p\,^4P_{1\frac{1}{2}}$, λ (air) 2143.888, and $3p^6\,^2S_{\frac{1}{2}}-(^3P)4p\,^4D_{1\frac{1}{2}}$, λ (air) 2021.759. Transitions from $(^3P)4p\,^4P_{\frac{1}{2}}$ and $^4D_{\frac{1}{2}}$ might also occur but the corresponding lines are masked by other argon lines. In the Schumann region only a few lines behaving experimentally like Ar II remain unclassified; one of these lines has an intensity of 2, the others are weaker.

Column 4 in Table 1 contains the wavenumbers calculated from the level scheme. With few exceptions the level values have been calculated from long wavelengths

Table 4. $(^3P)3d-(^3P)5f$ multiplets.

a

	$(^3P)5f\,^4D_{3\frac{1}{2}}$ 204 996.09	$5f\,^4D_{2\frac{1}{2}}$ 205 079.07	$5f\,^4D_{1\frac{1}{2}}$ 205 194.04	$5f\,^4D_{\frac{1}{2}}$ 205 180.36
$(^3P)3d\,^4P_{2\frac{1}{2}}$ 147 875.87	0.5 1 750.694 57 120.2			
$3d\,^4P_{1\frac{1}{2}}$ 147 503.03		1 1 736.830 57 576.2	1 1 733.362 57 691.4	
$3d\,^4P_{\frac{1}{2}}$ 147 227.97			1 1 725.138 57 966.4	0.5 1 725.549 57 952.6

b

	$(^3P)5f\,^4F_{4\frac{1}{2}}$ 204 937.80	$5f\,^4F_{3\frac{1}{2}}$ 204 951.09	$5f\,^4F_{2\frac{1}{2}}$ 204 977.59	$5f\,^4F_{1\frac{1}{2}}$ 205 056.22
$(^3P)3d\,^4D_{3\frac{1}{2}}$ 132 327.28	4 1 377.211 72 610.5	1 1 376.956 72 624.0		
$3d\,^4D_{2\frac{1}{2}}$ 132 481.15		3 1 379.884 72 469.9	1 1 379.377 72 496.5	
$3d\,^4D_{1\frac{1}{2}}$ 132 630.65			2 1 382.228 72 347.0	1 1 380.723 72 425.8
$3d\,^4D_{\frac{1}{2}}$ 132 737.62				1 1 382.765 72 318.9

c

	$(^3P)5f\,^4G_{5\frac{1}{2}}$ 205 100.53	$5f\,^4G_{4\frac{1}{2}}$ 205 104.32	$5f\,^4G_{3\frac{1}{2}}$ 206 148.94	$5f\,^4G_{2\frac{1}{2}}$ 206 255.23
$(^3P)3d\,^4F_{4\frac{1}{2}}$ 142 186.28	5 1 589.463 62 914.3			
$3d\,^4F_{3\frac{1}{2}}$ 142 717.03		2 1 602.893 62 387.2		
$3d\,^4F_{2\frac{1}{2}}$ 143 107.60			2 1 586.256 63 041.5	
$3d\,^4F_{1\frac{1}{2}}$ 143 371.36				2 1 590.229 62 884.0

and should be accurate to a few hundredths of a cm^{-1}. From such wavenumbers accurate wavelengths have been computed, the accuracy being estimated to be better than ±0.002 Å (Table 1, last column). Weak or blended lines are not included.

2. *The 762–487 Å range*

Some lines have been added to the list of previously known transitions to the ground term. $\lambda\lambda$ 679.221, 677.951, and 676.241 Å form the strong $3p^5\,^2P$–$(^3P)3d\,^4P$ multiplet, the $(^3P)3d\,^4P$ term having been found by de Bruin [5]. The strongest line, λ 676, occurs as an identified Ar III line in Boyce's list of 1935, but the identification was withdrawn later on [15]; its intensity vs. pulse power variation, as examined now, shows that it is certainly an Ar II line. Some new $3p^5\,^2P$–$(^3P)4d$ (doublet and quartet systems) lines have also been observed in addition to a strong transition, λ 612.372, from the recently located $(^1D)3d\,^2F_{2\frac{1}{2}}$ level [6].

Two lines, 560.224 Å and 556.817 Å, denoted $3p^5\,^2P_{\frac{1}{2}}$–$a\,^2P_{\frac{1}{2}}$ and $3p^5\,^2P_{1\frac{1}{2}}$–$a\,^2P_{1\frac{1}{2}}$, respectively, in Boyce's list, have now been identified as $^2P_{\frac{1}{2}}$–$(^1S)3d\,^2D_{1\frac{1}{2}}$ and $^2P_{1\frac{1}{2}}$–$(^1S)3d\,^2D_{2\frac{1}{2}}$; the remaining line in the multiplet, $^2P_{1\frac{1}{2}}$–$(^1S)3d\,^2D_{1\frac{1}{2}}$, has also been observed, its wavelength being 555.764 Å [6].

Below 500 Å a few new $3p^5\,^2P$–$(^3P)5d$ lines have been observed.

All Ar II lines below 762 Å observed in the present investigation are now identified.

Standard lines calculated from the accurate energy level scheme based on the author's measurements at longer wavelengths and Herzberg's measures of the two $3p^5\,^2P$–$3p^6\,^2S$ and four $3p^6\,^2S$–$(^3P)4p\,^2S,^2P,^2D$ lines in the vacuum ultraviolet are given in Table 2, column 6. As mentioned above they should be correct to ±0.0005 Å.

SUMMARY

The spectrum of singly ionized argon in the vacuum ultraviolet has been investigated with a 1.5 m concave-grating grazing-incidence spectrograph. The excitation was made by high-frequency pulses using previously described arrangements [7]. About 150 lines have been observed and

identified in the Schumann region, the majority being $({}^3P)3d$–$({}^3P)4f,5f,6f$ lines. There are also several $({}^3P)4s,3d$–$({}^3P)5p$ and $({}^3P)4p$–$({}^3P)6d$ lines as well as $({}^3P)3d$–$({}^1D)4f$ and $({}^1D)3d$–$({}^1D)4f,5f$ lines. New transitions to the $3p^6\,{}^2S$ level have also been observed.

In the region below 762 Å additional transitions to the ground term have been identified. From an accurate energy level scheme, based on the author's extensive measurements at longer wavelengths and fixed in relation to the ground term by using Herzberg's very accurate measurements in the vacuum ultraviolet, the wavelengths of about 70 ArII lines, well suited as standards, have been computed. Below 762 Å they should be accurate to ± 0.0005 Å.

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Tryckt den 22 december 1958

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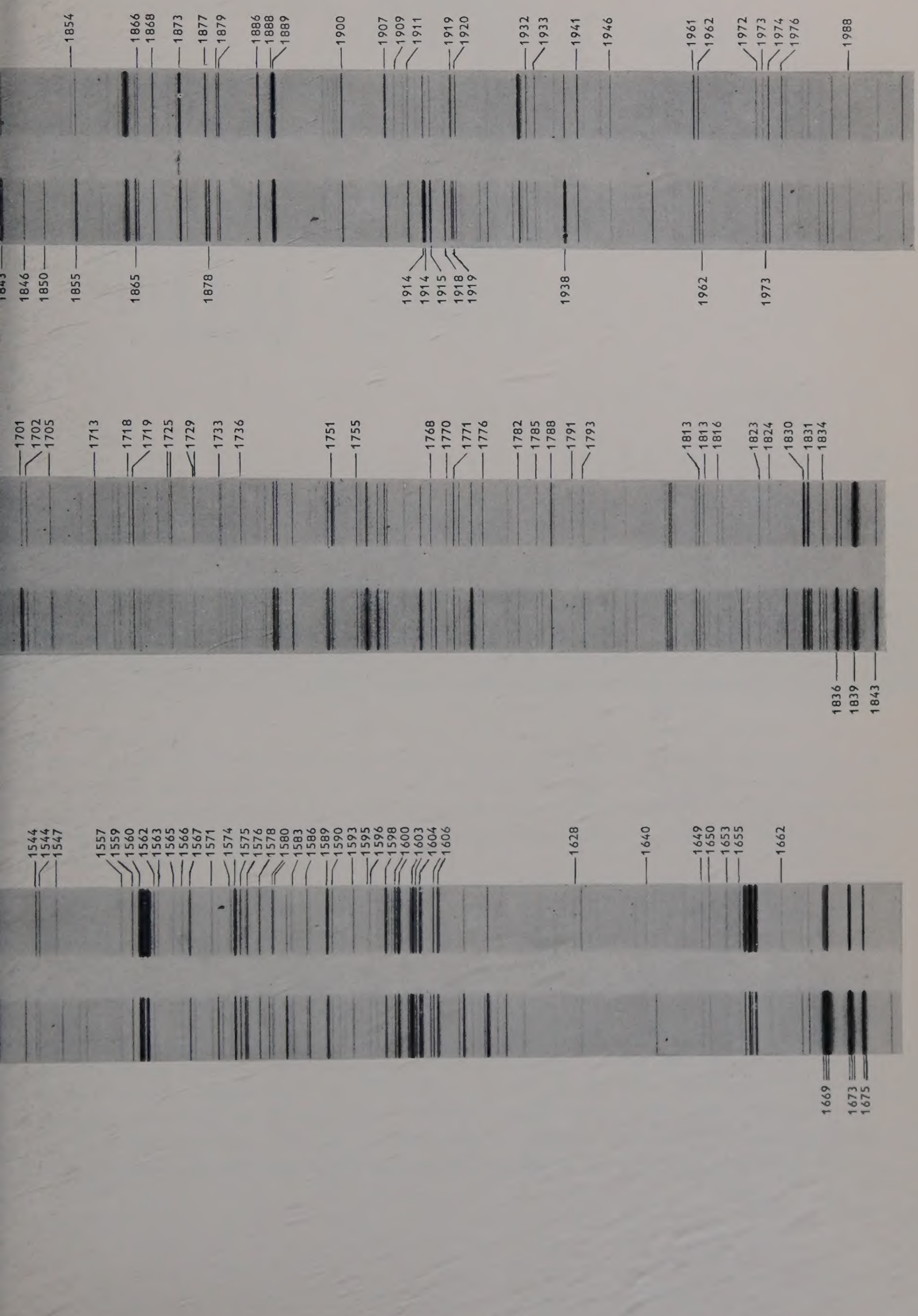
Description of Plates I–II

Argon spectra in the vacuum ultraviolet. The top spectrogram in each pair was taken under excitation conditions appropriate to develop Ar II; the lower spectrogram was obtained with greater high-frequency pulse power. Identified first-order Ar II lines are marked and also some Ar III and Ar IV lines, but not second or third order lines or impurities.

I and IId: Schumann region; IIe: 762–660 Å. Magnification: 4.8 times.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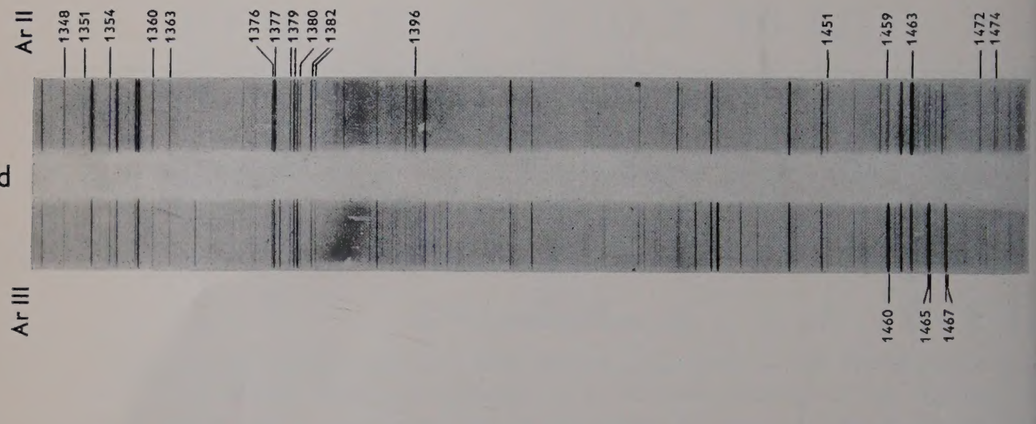
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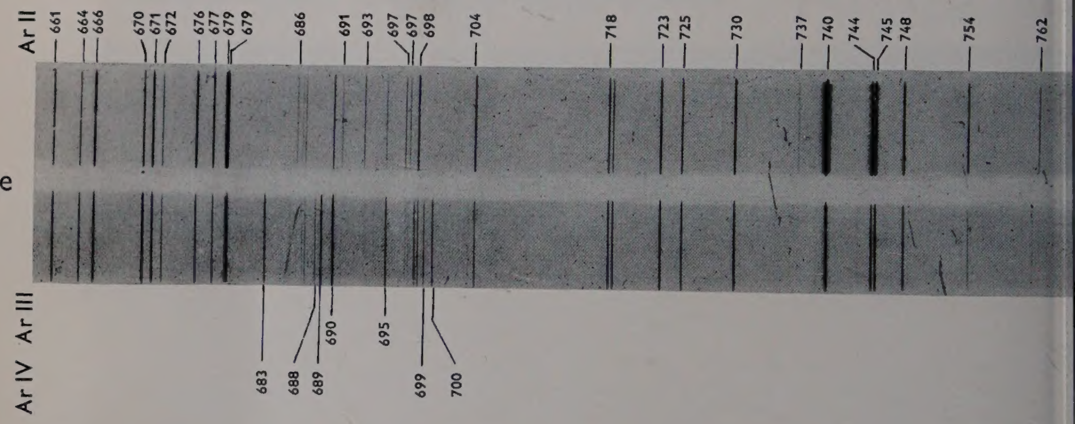
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